SDMS DOCID#1140393

Innovative Technical Solutions, Inc.
A Gilbane Company

Final Technical Memorandum

To:	Carmen White
From:	Rachel Hess, Jeff Hess, and Mark Sorensen
Date:	17 June 2011
Subject:	Review of Available Carson River Mercury Site OU2 Data and its Adequacy for Preparation of an OU2 Remedial Investigation Report
Contract /TO:	EP-S9-08-03/0024 **ITSI DCN:** 07163.0025.0033

1.0 INTRODUCTION

The Carson River Mercury Site is the only site in Nevada listed on the Superfund National Priorities List. The site includes mercury-contaminated soils at former mill sites, mercury contamination in waterways adjacent to the mill sites, and mercury contamination in sediments, fish and wildlife over more than a 50-mile length of the Carson River, beginning near Carson City, Nevada and extending downstream to the Lahontan Valley. Contamination at the site is a legacy of the Comstock mining era of the late 1800s, when mercury was imported to the area for processing of gold and silver ore. The United States Environmental Protection Agency (EPA) has identified two operable units at the Carson River Mercury Superfund Site (CRMS). Operable Unit 01 (OU01) addresses human health risks associated with direct exposure to surface soil with elevated mercury levels in the vicinity of Carson City, Virginia City, and Dayton, Nevada. Operable Unit 02 (OU2) addresses mercury contamination in the Carson River system, which includes contaminated sediments in the Carson River, Lahontan Reservoir, Carson Lake, and the Stillwater National Wildlife Refuge. This technical memorandum addresses OU2.

Numerous investigations have been conducted at the CRMS since 1973, long before it became a Superfund site. These investigations have generated a significant volume and variety of data, due in part to the size and complexity of the Carson River system which made it necessary to obtain a large set of data from various media, locations, and environments. The purpose of this memo is to evaluate the sufficiency of the available OU2 data for use in completion of a remedial investigation (RI) and feasibility study (FS) for the entire system below the mill sites, from:

- Carson River stretch from Dayton downstream to the Lahontan Reservoir ("OU2A");
- Lahontan Reservoir ("OU2B");
- Lower Carson River and irrigation canals and drains from below the Lahontan Dam to the wetlands ("OU2C");
- Lahontan Valley wetlands, including Stillwater National Wildlife Refuge and Carson Lake ("OU2D").

These are highly differing environments, and a variety of data are required to assess each one. In general, an RI requires the following major components:

- Identification of types of environmental contamination that could be harmful to human health or the environment, and assessment of the nature and extent of such contamination;
- Assessment of contaminant fate and transport, and development of a conceptual site model;
- An assessment of risk to human health (HHRA) and to ecological receptors (ERA);
- A feasibility study that assesses remedial methods for potential application at the site, based on a set of criteria including cost and effectiveness, among others.

The ultimate goal of the RI/FS is to support development of a Record of Decision (ROD) for the Carson River OU2.

Mercury has been identified as the primary contaminant affecting large portions of the Carson River system, as the result of extensive use of its metallic liquid form as an amalgamating agent to recover silver and gold from mines in the Comstock Lode near Carson City and Dayton. Based on the incomplete recovery of mercury from the amalgamation process, it has been estimated that approximately 15 million pounds of the metal was released at and near the mill sites, which were located near or along the shores of the Carson River or its tributary streams. Mercury is one of the most complex chemicals in terms of its chemical and environmental behavior; it is found in a variety of valences and forms in nature (metallic, inorganic, and organic), and it reacts with or sorbs to a variety of inorganic minerals and organic compounds and matter. It is of concern because of its toxic effects on most forms of life; its accumulation in fish and birds is of concern because of human consumption thereof, and because of potential deleterious effects to these animals and their reproductive prospects.

2.0 AVAILABLE DATA

There is an extensive history of sampling, investigations and research that have been conducted at the CRMS, beginning with Van Denburgh's finding that mercury was present in sediments below Dayton at levels 200 times above upstream background levels (Van Denburgh, 1973), complemented by Ritchins and Risser's findings showing levels of mercury in fish in the Carson River and Lahontan Reservoir at levels above those considered safe by the U.S. Food and Drug Administration (Richins and Risser, 1975). Subsequent sampling and investigation have looked at the various forms of mercury as well as other substances involved with its interactions, from contaminated source materials to ultimate removal from the system; these investigations have sampled tailings piles, soil, and alluvial fans in the source areas; floodplain sediments and soils along the river's entire reach; sediments in the channel of the river, in Lahontan Reservoir, in the various conveyances of the irrigation system, and in the downstream wetlands; groundwater and pore water in localized areas; air above the reservoir; and biota along the length of the system.

The various types of data have been listed in a semi-narrative table (Table 1) that is organized by the specific publication in which the data originally appeared. This narrows down considerably the list of publications; while there are hundreds of works in which data from the CRMS have appeared, many of these are studies delving into the behavior of mercury such as its sorption, inorganic reactions and complexation, methylation, evasion to the atmosphere, photochemistry, or anthropogenic sources; other papers postulate quantitative models to evaluate mercury flux in the reservoir or to evaluate geomorphic processes; still other studies are laboratory-based research into the various processes influencing the fate of mercury, such as microbial methylation and demethylation of mercury, the stability of chloride, sulfide and polysulfide complexes with mercury, or how mercury behaves in the presence of different types of organic matter. While these studies may have employed data or actual samples from the CRMS and are potentially very useful in understanding processes that may be occurring at CRMS, they are not primary data sources, and thus are not listed in Table 1. It is important to recognize, however, that many of these secondary sources are likely to be very useful in developing an understanding of mercury associated with the CRMS, and in developing a conceptual site model.

The number of biota samples from the CRMS is in the thousands, and there are many samples of the other types as well. For example, many surface-water sampling locations were re-visited on a regular basis (monthly or several times per year) in one or more consecutive years. Such studies are especially useful not only in terms of assessing nature and extent of contamination, but in developing an understanding of the changes in mercury behavior as a function of flow rates and geochemical parameters such as anoxic conditions that promote methylation. A challenge for the RI will be to organize the various types of data in a comprehensible fashion. However, there are several publications that summarize data for the major media sampled at the site, such as a technical memorandum published by Craft et al. (2005) that tabulates individual results for 380 fish from the Lahontan Reservoir, as well as to provide statistical information on the data set. Also included in that document are summaries of the available sediment and surface water data for mercury and methylmercury.

Table 1 contains, along with the standard bibliographic citations, information on the region covered by the study, the data quality, and summarized patterns or trends that can be observed in the data. The region covered by each study is also referred to by the shorthand designations 2A for the Carson River system upstream of the Lahontan Reservoir, 2B for the Lahontan Reservoir, 2C for the Carson River downstream of the reservoir, along with irrigation canals and drainage ditches, and 2D for the wetlands of the Lahontan Valley below the reservoir. Many studies cover more than one region of the Carson River system. Table 1 has been organized with two sets of columns grouped under the headings “Data Collected” and “Observations/Summary of Collected Data.” The “Data Collected” heading lists total sample quantities and analytical methods performed according to the major sample types, specifically sediment; surface water; overbank/floodplain sediments and soils; and biota. The “Observations/Summary of Collected Data” heading has very brief notes and observations from each study’s findings. Other notes of interest are listed in the last column.

It can be seen from Table 1 that the various source-data documents contain a significant number of sampling points from each of the four OU2 study areas, although OU2C is probably the least well-covered. Also, the four major sample types are well represented, with the number of biota samples in the thousands. Air samples are not well represented, however.

Remedial investigations can be performed using different types of sampling strategies. For a site of the size and diversity of environments as CRMS, a representative sampling scheme appears most appropriate. This means that sampling is conducted at specific locations that may be representative of specific locations or environments. In the context of CRMS, this could involve, for example, the collection of bank sediment samples directly facing the Carson River; data are thus gathered at very specific locations, but the data are representative of the types of sediments likely to erode at some future time and become suspended sediments or riverbed sediments; in either case, these newly-eroded materials could then contribute to the mass of mercury and methylmercury that have the potential to affect other elements of the system, including the surface water and biota. Another example of representative sampling is the collection of water samples during certain seasons – this is very frequently done at mercury-contaminated sites, because mercury very commonly follows seasonal patterns. For example, at CRMS, it has been observed that mercury and methylmercury in surface waters tend to reach high concentrations in the late spring, when the highest flows of the year occur. In many years, a second maximum often occurs for methylmercury (but usually not mercury) in the late summer, when temperature- and/or redox-driven methylation occur in certain sub-environments in the river and/or the reservoir. A representative or biased sampling program at specific times is useful to generate representative data about this seasonal phenomenon. Another representative sampling approach is provided by USGS data that are of greater frequency (roughly biweekly) but at a small number of locations; the ongoing USGS data from just two stations near Lahontan Reservoir (one upstream, one downstream) helps to define seasonal methylation occurring in the reservoir.

It appears that there are sufficient numbers of samples of the key affected media of sediments, surface waters, overbank deposits/soils, and biota, in all four portions of the CRMS, to develop an RI report that adequately assesses (in a representative manner) the nature and extent of mercury and methylmercury at the site. The fate and transport portion of the RI can be developed only if the various processes that determine mercury's behavior in the CRMS environment are understood. Because of the extent of the site, such an understanding must be developed at a conceptual level rather than simply on the basis of a listing or mapping of the various occurrences of elevated contamination.

3.0 ADEQUACY OF AVAILABLE DATA FOR RISK DECISIONS

As indicated above, the extent of mercury impacts at CRMS is significant, with mercury and methylmercury present in surface water, sediment, overbank deposits, soils and biota in the river system from Dayton to the terminal wetlands. Full recovery of all or most of the mercury released from the historic Comstock Lode may not be practical or possible, given the large area affected, the extensive residential and commercial land development, the agricultural importance of the waters of the Carson River, and presence of critical wetlands.

If full recovery cannot be practically achieved, then other methods of reducing mercury exposure to humans and ecological receptors need to be evaluated. These could include targeted remediation of impacted soils or sediments, including limited excavation of overbank deposits, dredging or capping of impacted sediments, construction/expansion of wetlands to enhance demethylation of the methylmercury in the surface water and sediment, to name just a few possible remedial actions, if such actions could be shown to result in a reduction in mercury exposure to humans and ecological receptors. To complete such an analysis, the data needs to be available to:

- Complete both a human health and ecological risk assessment in sufficient detail to serve as a baseline against which to evaluate possible remedial alternatives
- Understand causality behind the nature of the mercury resulting in any elevated risk to humans or ecological receptors
- Be able to demonstrate the likelihood of success of any future remedial action

To evaluate the adequacy of the existing data set for purposes of completing an RI, the data will be reviewed against the requirements for completing the above analysis, as identified below.

Human Health Risk

Reducing the potential human health risk from mercury would involve evaluating all aspects of potential human exposure to mercury, including:

1. Inhalation of impacted dust and/or vapor
    a. Is Hg present in the surface materials available for wind-blown transport?
    b. Is Hg volatilizing from soils, sediment deposits, or impacted surface waters?

2. Ingestion of impacted water, food (e.g., fish) and crops irrigated with impacted surface water and/or groundwater
    a. Are impacted fish or other impacted biota being used as recreational or subsistence food sources?
    b. Are crops irrigated with Carson River water impacted, and are they a food source for biota or humans?
    c. Is Hg present in groundwater at levels that may pose a risk if ingested?
3. Dermal exposure to impacted soil, sediment, surface water and/or groundwater
    a. Is Hg present in surficial soils and sediments where humans may be exposed by direct contact?
    b. Is Hg present in surface water at levels that may pose a risk to humans if exposed through wading or swimming?
    c. Is Hg present in groundwater at levels that may pose a risk if used for washing or showering?

Ecological Risk

Reducing the impacts to fish, birds and other ecological receptors would include evaluating potential routes of exposure, including:

1. Conversion of mercury into more readily bioavailable methylmercury
    a. What are the cause(s) of the conversion of Hg to MeHg
    b. Where is the conversion occurring?
2. Entry of methylmercury into the food chain
    a. Is MeHg entering the food chain at the lowest trophic levels (e.g., phytoplankton) and biomagnifying up the food chain?
3. Bioaccumulation and biomagnification of mercury in higher trophic levels
    a. Is MeHg bioaccumulating in and biomagnifying up the food chain (e.g., phytoplankton to zooplankton [microinvertibrates] to insects [macroinvertebrates] to fish to piscivorous fish and birds?
4. Direct exposure of fish and birds to methylmercury in surface water
    a. Does direct exposure to elevated Hg in surface waters have any effect on the higher trophic levels?

Table 2 presents the above factors and identifies available data to support the analysis of the risk factors. Some of these risk factors were evaluated in previous studies, including the Human Health Risk Assessment and Remedial Investigation Report (EPA, 1994) for the entire CRMS, and the Ecological Risk Assessment (E&E, 1998) performed for OU1 and portions of OU2 (upstream of Lahontan Reservoir). Others have been addressed in, for example, mercury methylation-demethylation studies performed at the site or using samples from CRMS.

Overall, there appears to be adequate data to prepare a representative RI, especially as it relates to estimating risk to human health and the environment. However, the full nature and extent of Hg in the environment is incomplete. For example, the nature and extent of both impacted sediment in overbank deposits and soil in the floodplain above Lahontan Reservoir is not well defined, and the extent of impacted sediments in the agricultural drains and terminal wetlands is only partially defined. Also, the Carson River is used to irrigate crops below Lahontan Reservoir, and no studies were identified in the data reviewed to date that evaluate whether the sustained presence of Hg and MeHg in the surface water used for irrigation has had any adverse impacts on crops.

4.0 CONCEPTUAL SITE MODEL

The generation of representative data can help in developing a conceptual understanding of the various processes that determine the fate and transport of mercury at CRMS as long as all the various environments, media, and processes are represented in the data set. With the exception of data discussed above and in Table 2, it appears that, in general, the critical data needed to prepare a (representative) RI are indeed available for the site, as summarized on Table 1.

We believe that it will be useful to develop a detailed conceptual site model to complete a major section of the RI, which is intended to account for the fate and transport of mercury and methylmercury at the CRMS, as well as to assist in the risk assessment and FS. The reasons behind developing a detailed conceptual site model are:

- The CRMS is a very large site with a very large number of samples collected through the years, from a great variety of chemical, geomorphic, and biological environments. An approach of primarily tabulating accumulated results could lead to emphasis on either localized or ephemeral patterns that may not have significance on the scale of a large system where the relevant exposures to biota are likely to be a function of feeding in multiple areas and across multiple seasons. In such a context, individual results become less important than larger-scale patterns and processes.

- Methylmercury appears to be present at levels of potential concern in both sediments and surface waters along the entire length of the Carson River system downstream from the Comstock Lode mill sites. However, it is important to know whether there are specific controls on this distribution, so that questions on mercury exposure can be addressed. For example, is methylmercury cycled on a short time-scale and continually produced and degraded as a function of local availability in sediment? It is known that part per million (ppm) levels of total mercury and part per billion (ppb) levels of methylmercury are present in sediments from Dayton all the way to the wetlands in the Carson Desert. Furthermore, it appears that methylmercury is correlated with total mercury in both surface water and sediment in much of the watershed. If methylmercury is continually produced due to the presence of high levels of total mercury in sediment, then this is knowledge that feeds into evaluation of any potential remedial options.
- If, on the other hand, methylmercury is produced primarily seasonally, then another set of remedial options may become feasible. For example, it is known from the Cooper et al. (1983) limnology study of the Lahontan Reservoir across two seasons that the reservoir is susceptible to stratification in late summer, and that a significant volume (about 40%) of reservoir water is part of the DO-depleted hypolimnion. Sulfide was documented at shallow depths (top 10 centimeters) in reservoir bottom sediment, demonstrating the occurrence of sulfate reduction and a possible methylating environment. USGS data documents methylmercury at relatively high levels (> 8 ng/L) coinciding with low DO values (near 4 mg/L) in water downstream from the reservoir in late summer in two recent seasons, and at moderate levels (about 1 ng/L) in two other seasons among the past 11. If this is a recurring pattern, then it may be possible to address a volumetrically significant source of methylmercury to both the reservoir and the downstream areas.
- Developing remedial alternatives as part of an FS is more readily envisioned when the temporal and spatial processes governing contaminant exposure are understood, such as the occurrence of methylation. It may be that both scenarios above (both ongoing and seasonal methylation) account for volumetrically significant proportions of methylmercury at CRMS; this knowledge would also be important in developing and evaluating remedial alternatives.

5.0 REFERENCES CITED

Craft, D., Fields, J., and Yoder, N., 2005. Mercury in the Carson River Basin, California and Nevada. Technical Memorandum TSC-2005-8290-001, U.S. Dept. of the Interior, Bureau of Reclamation.

Richins, R.T., and Risser, A.C., Jr., 1975. Total mercury in water, sediment, and selected aquatic organisms, Carson River, Nevada, 1972: Pesticides Monitoring Journal vol. 9, p. 44-54.

Van Denburgh, A.S., 1973. Mercury in the Carson and Truckee River Basins of Nevada. U.S. Geological Survey Open-file Report 73-352, 15 p.

Table 1
Summary of Available Primary Data
Carson River Mercury Site, OU2

Reference	Year Published	Data Collected				Region	Data Quality
		Sediments	Surface Water	Overbank/Floodplain/ Soil	Biota		
Azad, G., 2008. Carson River aquatic life status report, December 2007. Prepared for Nevada Dept. Environmental Protection, Carson City, NV.	2008	–	–	–	15 fish fr Carson R below Carson City, 19 upstrm, sampled 2006	East Fk Carson to main stem at Ft Churchill **(2A)**	
Bonzongo, J. C., Heim, K. J., Chen, Y., Lyons, W. B, Warwick, J.J., Miller, G.C., and Lechler, P.J., 1996. Mercury Pathways in the Carson River-Lahontan Reservoir System, Nevada, USA. Environmental Toxicology and Chemistry v. 15, pp. 677-683.	1996	See bank samples at right	10 locations sampled in 3 flow regimes & analyzed for HgT, MeHg (unfiltered), Hg(II) acid-reactive HgT, dissolved Hg(II); depth-specific splg in Lahontan Res at 5 depths, analyzed for total & dissolved HgT & MeHg	Bank samples collected from 6 locations upstream of Lahontan, analyzed for HgT, MeHg	–	Carson City to Lahontan Dam **(2A, 2B)**	High
Bonzongo, Jean-Claude J., Nemer, Bassel W., and Lyons, W. Berry, 2006. Hydrologic controls on water chemistry and mercury biotransformation in a closed river system: The Carson River, Nevada: Applied Geochemistry v. 21, p. 1999-2009.	2006	–	Same 3 locations as at right, sampled for unfiltered & filtered HgT & MeHgT, plus major anions, oxyanions, pH, TSS	3 locations upstream , at Ft Churchill, & in Stillwater WR, analyzed for HgT, MeHgT, potential methylation & demethylation rates	–	3 isolated locations: upstrm from contam in Genoa, at Ft Churchill, & in Stillwater WR **(2A, 2D)**	Not clear; specific sampling methods & locations not well described. Also, units in Tbl 1a appear to be off.
CH2M Hill, Inc., 2008. Data evaluation report, Carson River mercury load from bank erosion, Carson River mercury site, Lyon, Storey, and Churchill counties, Nevada. Draft. Prepared for U.S. Environmental Protection Agency, Region 9, San Francisco, CA.	2008	–	Constructed plots of dischg vs HgT at Weeks Bridge	50 spls from 10 locations, ea of the 50 being a vertical composite of bank material; analyzed for HgT, MeHg	–	Dnstrm portion of upper Carson R between Ft Churchill & Weeks Bridge **(2A)**	High
Cooper, J.J., Vigg, S., Bryce, R.W., and Jacobson, R.L., 1983. Limnology of the Lahontan Reservoir, Nevada, 1980-1981. Publication 50021 of Bioresources and Water Resources Center, Desert Research Institute, Univ. of Nevada, Reno, Nevada.	1983	Lake-bottom cores collected from 0-10 cm at 4 locations & analyzed for HgT, sulfide, other inorganics	Reservoir was profiled at 4 locations, sampled at 5, monthly from Feb 1980-Oct 1981. Also collected pore-water samples from near-shore at ~6 locs & analyzed for major ions, nutrients	–	~80 samples fish, 3 crayfish, 4 gulls	Lahontan Res only **(2B)**	Probably high, but an older study

Reference	Observations/Summary of Collected Data				Notes of interest
	Notes on Sediment Splg Results	Notes on Water Splg Results	Note on Overbank/Floodplain/ Soil Sampling Results	Notes on Biota Splg Results	
Azad, G., 2008. Carson River aquatic life status report, December 2007. Prepared for Nevada Dept. Environmental Protection, Carson City, NV.				Upstrm range 0.04 – 0.22 ppm Hg; dnstrm range 0.99 – 11.27 ppm (highest fr sm bass at Ft Churchill)	
Bonzongo, J. C., Heim, K. J., Chen, Y., Lyons, W. B, Warwick, J.J., Miller, G.C., and Lechler, P.J., 1996. Mercury Pathways in the Carson River-Lahontan Reservoir System, Nevada, USA. Environmental Toxicology and Chemistry v. 15, pp. 677-683.		Highest HgT (7585 ng/L) & MeHg (7.2 ng/L) at Ft Churchill & Carson R delta. In Lah Res., MeHgT was higher in near-surf oxic water than anoxic water at 9 & 12 m, but not by a lot (and there's only 1 profiled location) - poss due to bioaccumula in phytoplankton; a lesser inc in hypolimnion MeHg cd be due to scavenging by Mn oxides (MeHgT increases, but MeHgD stays constant w depth	Range up to ~610 ppm HgT, 15 ppb MeHg, highest at Ft Churchill gage & Ft Churchill		They note that vertical distribution of MeHg declines w depth in reservoir. Speculate that Gp VI anions inhibit sulfate-reducing bacteria, along w high pH. However, their data set in reservoir is only a single location at 5 depths to 12 m, although they did get well below thermocline of 6 m (& Mn inc'd w depth >6m).
Bonzongo, Jean-Claude J., Nemer, Bassel W., and Lyons, W. Berry, 2006. Hydrologic controls on water chemistry and mercury biotransformation in a closed river system: The Carson River, Nevada: Applied Geochemistry v. 21, p. 1999-2009.		Hg concentrations inc dnstrm, but MeHg is fairly high in upstream location (14% of HgT cf 1% of HgT at dnstrm locations)	Hg concentrations inc dnstrm, but MeHg is actually highest in upstream seds (6 ppb). Also, % MeHg decrs dnstrm – hypothesized due to more dilute water w lower pH & oxyanions & lower demethylation rates in the upstrm location; also %MeHg incs w flow at all locations – hypothesized due to dilution w flow by above mechanisms		Interesting points, but not a lot of data to support the hypotheses
CH2M Hill, Inc., 2008. Data evaluation report, Carson River mercury load from bank erosion, Carson River mercury site, Lyon, Storey, and Churchill counties, Nevada. Draft. Prepared for U.S. Environmental Protection Agency, Region 9, San Francisco, CA.	Generally inc's dnstrm to Weeks Brdge, correlates w fines + TOC; MeHg correl w HgT, but is only ~0.01% of HgT; concentrations ~homogenous w/i a location				
Cooper, J.J., Vigg, S., Bryce, R.W., and Jacobson, R.L., 1983. Limnology of the Lahontan Reservoir, Nevada, 1980-1981. Publication 50021 of Bioresources and Water Resources Center, Desert Research Institute, Univ. of Nevada, Reno, Nevada.	Hg ranges 1.2 - 23 ppm; S= elevated in 3 of 5 samples, up to 0.40 ppm -> sulfide reduction in shallow seds, & potential Hg methylation	Stratification in July & August below 10-12 m both yrs (1980&81); DO declines to <3 mg/L near bottom (as shallow as 7 m) at 3 of 4 profiles and pH is 1-2 units lower than at surf. NO3 and SO4 depletion in wtr is not apparent, but anoxic conditions do exist at shallow depth in sediment, based on $S^{=}$. Turnover in Sept in both years resulted in cplt mixing of hypolimnetic & epilimnetic waters, & DO declined to ~60% of saturation (thus hypolimnetic w must have been about 40-50% of total volume!). The reservoir is nitrogen-limited based on inorganic N:P ratios, and NO3 becomes depleted in summer.		0.11 to 9.52 ppm wet wt, highest in bass, crappie, & crayfish; 68% of fish were above 1 pm/kg FDA action level	Excellent limnological study – reports on eutrophic conditions & harmful effects to lake ecosystem, which include blooms of blue-green algae, decreased overall productivity (blue-greens cannot be consumed by zooplankton), & O2 depletion (fosters Hg methylation). They estimate lake volumes affected by hypolimnetic conditions upon mixing in fall, & resultant PO4 & sulfide concentrations. Looked at nutrient loading & recommend reducing load to this eutrophic res., but decreasing N would advantage blue-greens, while decreases in P would have to be at least 66% to be at all significant, as the system is N-limited, not P-limited.

Table 1
Summary of Available Primary Data
Carson River Mercury Site, OU2

Reference	Year Published	Data Collected				Region	Data Quality
		Sediments	Surface Water	Overbank/Floodplain/ Soil	Biota		
Cooper, James J., Thomas, Richard O., and Reed, S. Michael, 1985. Total mercury in sediment, water, and fishes in the Carson River drainage, west-central Nevada. Nevada Division of Environmental Protection, Carson City, NV. December.	1985	75 samples from river bottom (15 locations on 5 dates each) analyzed for HgT	15 locations sampled on 16 dates for HgT, but RL was 0.5 ug/L	60 spls (15 locations on 4 dates each) fr a dark "Hg-rich" layer along the banks	333 fish from 15 locations different from the sediment & water spls	Entire system from Carson City to Carson Sink **(2A, 2B, 2C, 2D)**	Good for biota; fair to poor for water
Craft, D., Fields, J., and Yoder, N., 2005. Mercury in the Carson River Basin, California and Nevada. Technical Memorandum TSC-2005-8290-001, U.S. Dept. of the Interior, Bureau of Reclamation.	2005	Summary of available data thru 2004 (s+C13pls fr above Carson City to below dam)	Summary of available data thru 2004 (139 spls from Woodfords to below dam)	–	Summary of existing data, including 475 fish from Lahontan Res., separated according to forage and predator	Entire system **(2A, 2B, 2C, 2D)**	High, but note that studies vary in season & coverage & probably methods
Custer, M.C., Custer, T.W., and Hill, E.F., 2007. Mercury Exposure and Effects on Cavity-Nesting Birds from the Carson River, Nevada. Archives of Environmental Contamination & Toxicology. DOI: 10.1007/s00244-006-0103-6.	2007				Tree swallows and house wrens from above and within the mining impacted areas.	Upper Carson River (**2A**)	Higb
Gustin, M.S., 2001. Mercury Emissions from Lake Lahontan: A 24 Hour Study. Prepared for U.S. Environmental Protection Agency	2001		Surface water and air samples from a single location over a 24-hour period			Lahontan Reservoir (**2B**)	High
Gustin, M.S., Taylor, G.E., Jr., and Leonard, T.L., 1994. High levels of mercury contamination in multiple media of the Carson River drainage basin of Nevada: Implications for risk assessment. Environmental Health Perspectives, v. 102, no. 9.	1994	23 HgT fluvial, alluvial & lacustrine seds	10 for HgT & MeHg from Lahontan Res.(6 spls), Sixmile Ck. (2), Lousetown Ck (2; background)	38 samples of mill tailings, 8 soils & rock	Used data fr Hoffman et al., 1990 Recon inv irriga drng, Stillwater (ref 6), & Cooper, Thomas &Reed, 1985 (ref 12)	Sixmile Cyn to Lahontan **(2A, 2B)**	High
Henny, C.J., Hill, E.F., Grove, R.A., and Kaiser, J.L., 2007. Mercury and drought along the lower Carson River, Nevada, I. Snowy egret and black-crowned night-heron annual exposure to mercury, 1997-2006. Rchives of Environmental Contamination & Toxicology. DOI: 10.1007/s00244-006-0163-7.	2007	–	7-13 locations above & below Lahontan R., 2-3 times annually from Apr 1 to ~ July 15 for 10 yrs, analyzed for unfiltered HgT & MeHg	–	~400 spls eggs & blood of young egrets & herons fr nests on 2 islands in reservoir; geometric means provided	Lahontan & just below reservoir **(2B, 2C)**	High
Hoffman, R.J., and R.L. Taylor, 1998. Mercury and Suspended Sediment, Carson River Basin, Nevada: Loads To and From Lahontan Reservoir in Flood Year 1997 and Deposition in Reservoir Prior to 1983, Fact Sheet 001-98, U.S. Department of the Interior, U.S. Geological Survey.	1998	3 cores collected from 80' depth 0.5 mi S of dam & age-dated with Cs-137, & one measured for HgT	18 samples at Ft Churchill, 8 at the "Below Lahont Res" station, analyzed for HgT & MeHgT	–	–	Lahontan Res area **(2B)**	High
Hoffman, R.J., and Thomas, K.A., Methylmercury in Water and Bottom Sediment along the Carson River System, Nevada and California, September 1998. Water-Resource Investigations Report 00-4013. U.S. Geological Survey.	2000	19 samples analyzed for THg & TMeHg	19 unfiltered samples analyzed for THg & TMeHg	–	–	Upstream & downstream from Lahontan Res. **(2A, 2C, 2D)**	High

Table 1
Summary of Available Primary Data
Carson River Mercury Site, OU2

Reference	Observations/Summary of Collected Data				Notes of interest
	Notes on Sediment Splg Results	Notes on Water Splg Results	Note on Overbank/Floodplain/ Soil Sampling Results	Notes on Biota Splg Results	
Cooper, James J., Thomas, Richard O., and Reed, S. Michael, 1985. Total mercury in sediment, water, and fishes in the Carson River drainage, west-central Nevada. Nevada Division of Environmental Protection, Carson City, NV. December.	Hg increased fr 0.08 ppm upstream fr New Empire to 5.44 ppm below Lahontan Res. State that Hg is widespread though at lower levels below dam, including irrigation canals, Indian Lakes cplx, & Carson Lk.	Peak levels at Weeks Bridge above Lahontan, but note v high RLs; water Hg is correl to sediment Hg, & to river discharge (e.g., spring flows). Lah Res retained 95% of influent Hg fr May 83- Apr 84		Fish ranged from 0.06 - 4.14 ppm ww, with game fish & carp highest. Dnstrm fr Dayton, 45% of fish >1 ppm Hg. Ft Churchill highest, followed by Lah Res., wetland lakes; relatively low at Dayton.	
Craft, D., Fields, J., and Yoder, N., 2005. Mercury in the Carson River Basin, California and Nevada. Technical Memorandum TSC-2005-8290-001, U.S. Dept. of the Interior, Bureau of Reclamation.	Hg values increase all the way to upper reservoir & the Narrows. Cite Hoffman data on sed cores fr lower reservoir showing Hg conc of newly-deposited seds has declined since mid-1940s from 6000-8000 ppb to ~4000 in 1982.			Good observations on predator fish in Lah. Res. avg = 3.03 ppm wet wt (includes a walleye at 16 ppm), forage fish avg = 0.94 ppm	Also summarizes other relevant research
Custer, M.C., Custer, T.W., and Hill, E.F., 2007. Mercury Exposure and Effects on Cavity-Nesting Birds from the Carson River, Nevada. Archives of Environmental Contamination & Toxicology. DOI: 10.1007/s00244-006-0103-6.				Concentrations of Hg in eggs was 6.2-9.2 ug/g, whereas upstream of the mining impacted areas the concentrations were 0.24 ug/g	
Gustin, M.S., 2001. Mercury Emissions from Lake Lahontan: A 24 Hour Study. Prepared for U.S. Environmental Protection Agency		46 samples of air samples from a single location over a 24-hour period to evaluate variations in emissions of Hg from impacted surface water. Results indicate emissions equal approx. 0.3% of Hg in water.			
Gustin, M.S., Taylor, G.E., Jr., and Leonard, T.L., 1994. High levels of mercury contamination in multiple media of the Carson River drainage basin of Nevada: Implications for risk assessment. Environmental Health Perspectives, v. 102, no. 9.	HgT in fluvial & alluvial up to 156 ppm & lacustrine seds up to 103 ppm	Water from Res ranges to 591 ng/L HgT & 21 MeHg), Sixmile Ck. to 35,400 ng/L, Lousetown Ck is background (10 ng/L)	Mill tailings range 2.9-1,610 ppm		ALSO has atmospheric data – 28 spls – highest in N America
Henny, C.J., Hill, E.F., Grove, R.A., and Kaiser, J.L., 2007. Mercury and drought along the lower Carson River, Nevada, I. Snowy egret and black-crowned night-heron annual exposure to mercury, 1997-2006. Rchives of Environmental Contamination & Toxicology. DOI: 10.1007/s00244-006-0163-7.		Total discharge pos related to HgT but not MeHg; below reservoir, flow positively related to MeHg in wtr. Thus reserv is impt site of methyla. (However, MeHg concentrations below res are 10x lower than above)			Key relationship was MeHg in birds to MeHg in unfiltered water below reservoir. (But are birds feeding mostly above or below res.? If above, why are their MeHg levels related to MeHg below res?)
Hoffman, R.J., and R.L. Taylor, 1998. Mercury and Suspended Sediment, Carson River Basin, Nevada: Loads To and From Lahontan Reservoir in Flood Year 1997 and Deposition in Reservoir Prior to 1983, Fact Sheet 001-98, U.S. Department of the Interior, U.S. Geological Survey.	Hg conc of newly-deposited seds has decliined since mid-1940s from 6000-8000 ppb to ~4000 in 1982 (stiil is 30x that of L. Owyhee, OR)	HgT ranges 260-28,000 ng/L, MeHgT 1.44-5.24 ng/L & were correlated to streamflow			Reservoir in Jan-Sept 1997 retained 90% of the sediment & 80% of total Hg that flowed past Ft Churchill. Summer values indicate only ~67% of MeHg retained by reservoir (but they didn't collect MeHg in Jan-May)
Hoffman, R.J., and Thomas, K.A., Methylmercury in Water and Bottom Sediment along the Carson River System, Nevada and California, September 1998. Water-Resource Investigations Report 00-4013. U.S. Geological Survey.	Upstrm of res., TMeHg & THg highest (7.35 ppb & 4.13 ppm) at Ft Churchill; TMeHg even higher dnstrm (13 & 22 ppb) in ag drains entering Stillwater NWR (upstrm background 3 ppb); THg 13.1 ppm at Stillwater Slough	TMeHg highest (7.83 ng/L) in transi zone at Carson delta into Lahontan, but 2 dnstrm wetlands had 3 ng/L (upstrm background 0.2 ng/L). THg up to 9,040 ng/L at delta, declining to 782 at inflow to Stillwater Pt Res			Strong positive correla of TMeHg in water with THg in sed; moderate correlation of TMeHg in wtr with THg in wtr, and of these species in sed. Weaker correlations of MeHg in water with water temp., pH, TOC

Table 1
Summary of Available Primary Data
Carson River Mercury Site, OU2

Reference	Year Published	Data Collected				Region	Data Quality
		Sediments	Surface Water	Overbank/Floodplain/ Soil	Biota		
Hoffman, R.J., Hallock, R.J., Rowe, T.G., Lico. M.S., Burge. H.L., and Thompson, S.P., 1990. Reconnaissance investigation of water quality, bottom sediment, and biota associated with irrigation drainage in and near Stillwater Wildlife Management Area, Churchill County, Nevada, 1986-87. U.S. Geological Survey Water-Resources Investigations Report 89-4105. Carson City, Nevada.	1990	20 samples from lakes & drains, including 3 background sample, to 2"-3.5" depth	24 surface w. including 4 background for HgT; 6 groundwater spls (RL = 0.1 ug/L or 100 ng/L)	–	305 birds, 88 fish, 45 invertebrates 212 plants analyzed for dry-weight Hg	Stillwater WMA - focuses on irrigation drainage effects from any water-quality problem **(2C, 2D)**	High, although RL for Hg in water is 0.1 ug/L; reported as dry wt
Marvin-DiPasquale, M., Agee, J., Krabbenhoft, D., and Oremland, R.S., 2001. Methylmercury formation and degradation in sediments of the Carson River system. Report submitted to Wayne Praskins, U.S. EPA Region IX, San Francisco, in fulfillment of EPA Interagency Agreement DW14955409-01-0. December 17.	2001	13-14 sites sampled 3 times including summer & fall (high & low water) seasons, 0-4 cm, incubated & studied for net MeHg production (including org matter, redox, sulfide, Hg(II), etc.)	Pore water only from same sites; analyzed for anions	One depth profile study of vertical bank sediment done for MeHg production (0-16 cm, 4 intervals), incubated/studied as sed samples	–	Entire system – river, reservoir, Carson Sink playa, agricultural drains, Lahontan V. wetlands **(2A, 2B, 2C, 2D)**	High
Miller, J.R., Barr, R., Grow, D., Lechler, P., Richardson, D., Walman, K., and Warwick, J., 1999. Effects of the 1997 flood on the transport and storage of sediment and mercury within the Carson River valley, west-central Nevada: J. Geology, v. 107, p. 313-327.	1999	~23 locations where channel-bed sediments sampled before & after 1997 flood & analyzed for HgT	–	~23 locations where overbank deposits sampled before & after 1997 flood & analyzed for HgT	–	Carson City to ~Weeks Bridge **(2A)**	High; however, specific data not tabulated but only on graphs or as mean values for a strat unit
Miller, J.R., Lechler, P.J., Rowland, J., Desilets, M., and Hsu, L.-C., 1996. Dispersal of mercury-contaminated sediments by geomorphic processes, Sixmile Canyon, Nevada, USA: Implications to site characterization and remediation of fluvial environments. Water, Air, and Soil Pollution, v. 86, pp. 373-388.	1996	22 HgT samples of pre-mining (weathered & with soil/colluvium) & post-mining fan deposits, & the modern channel	–	(Alluvial fan deps – see seds column)	–	Sixmile Canyon fan near Dayton **(2A)**	High – integrated w geomorphic mapping
Miller, J.R., Lechler, P.J., Rowland, J., Desilets, M., and Hsu, L.-C., An Integrated Approach to the Determination of the quantity, Distribution, and Dispersal of Mercury in Lahontan Reservoir, Nevada, USA. J Geochem. Expl. Vol. 52, pp. 45-55.	1995	78 samples analyzed for HgT; samples subdivided according to stratigraphic units	–	–	–	Lahontan Reservoir only (sampled in trenches during a dry year) **(2B)**	High
Rowe, T.G., Lico, M.S., Hallock, R.J., Maest, A.S., and Hoffman, R.J., 1991. Physical, chemical, and biological data for detailed study of irrigation drainage near Stillwater, Fernley, and Humboldt Wildlife Management Areas and Carson Lake, west-central Nevada, 1987-89. U.S. Geological Survey Open-File Report 91-185. Carson City, Nevada.	1991 (follow-up to Hoffman et al., 1990)	11 locations from Stillwater, 5 from Fernley WMA, each analyzed in 2 particle size fractions for metals including HgT	58 sites for HgT; 26 groundwater spls	–	515 samples fr 100 sites (455 bird's egg, muscle & unspecified parts, 12 inverts, 87 plants) analyzed for dry-wt Hg	Stillwater, Fernley, and Humboldt Wildlife Management Areas and Carson Lake (includes ~1/3 of data from outside Carson system) **(2C, 2D)**	High, but Hg RLs in water are 0.1 µg/L; reported as dry wt
Tidball, R.R., Briggs, P.H., Stewart, K.C., Vaughn, R.B., and Welsch, E.P., 1991. Analytical data for soil and well core samples from the Carson River basin, Lyon and Churchill counties, Nevada. U.S. Geological Survey Open-File Report 91-584A. 140 p.	1991			Soil 0-12" on grid pattern across entire drainage basin, and subsurface soils to water table (locally 90 ft) in well cores in alluvial areas only		Entire system from Carson City to Carson Sink **(2A, 2B, 2C, 2D)**	High
Tuttle, P.L., and Thodal, C.E., 1998. Field screening of water quality, bottom sediment, and biota associated with irrigation near the Indian Lakes area, Stiilwater Wildlife Management Area, Churchill County, west-central Nevada, 1995. USGS Water-Resources Investigations Report 97-4250	1998	8 samples of bottom seds analyzed for Hg	3 seepage ponds analyzed for Hg at 0.1 ug/L in 1994; no subsequent analyses for Hg in 1995	–	16 inverts (8 above, 8 below the dietary effect concentration of 0.5 ppm); 6 avian eggs & 5 avian livers (mainly avocets)	Indian Lakes area of Stillwater WMA **(2D)**	Water data quality low (high RL for Hg); bio data probably high-quality

Table 1
Summary of Available Primary Data
Carson River Mercury Site, OU2

Reference	Observations/Summary of Collected Data				Notes of interest
	Notes on Sediment Splg Results	Notes on Water Splg Results	Note on Overbank/Floodplain/ Soil Sampling Results	Notes on Biota Splg Results	
Hoffman, R.J., Hallock, R.J., Rowe, T.G., Lico. M.S., Burge. H.L., and Thompson, S.P., 1990. Reconnaissance investigation of water quality, bottom sediment, and biota associated with irrigation drainage in and near Stillwater Wildlife Management Area, Churchill County, Nevada, 1986-87. U.S. Geological Survey Water-Resources Investigations Report 89-4105. Carson City, Nevada.	Most are dark, fine, anaerobic (H2S odor) muds. Range 0.04 – 18 ppm (highest at Carson Lake & then Stillwater Slough (an old Carson R channel) at 14 ppm.	All Hg results < RL & thus below federal or state criteria for aq life protection (but RL high)		Many birds & inverts are above effects levels or public health warning levels; fish are mostly below effects levels, but mostly above bird diet effect levels (see Figs 21-25, Tbl 19)	Public health warning issued in 1989 on tissue from shoveler ducks from Carson Lake due to Hg content (~150 ppm dry wt)
Marvin-DiPasquale, M., Agee, J., Krabbenhoft, D., and Oremland, R.S., 2001. Methylmercury formation and degradation in sediments of the Carson River system. Report submitted to Wayne Praskins, U.S. EPA Region IX, San Francisco, in fulfillment of EPA Interagency Agreement DW14955409-01-0. December 17.	High net methylation in river upstream from reservoir (Ft Churchill) & in delta where river enters reservoir; lowest in N (lower) Lah Res., upstrm control site, & Carson playa	Positive correl of sed HgT & MeHg, & Hg(II) (indicates bioavailability to methyla). Majority of Hg(II) avail for methyla was assoc w sed, not pore-wtr. Bioavail Hg low where $S^{=}$ high (charged $S^{=}$ cplx). Gross MeHg degrada correls w pore-wtr & sed $S^{=}$, with methanogenesis, & sediment tot C (but oxidative demethyla is still primary pathway for anaerobic			Radiolabeling expts supported Hg(II) being a function of low $S^{=}$. Anaerobic microbial metabolism highest in wetlands --> fast degradation of MeHg there.
Miller, J.R., Barr, R., Grow, D., Lechler, P., Richardson, D., Walman, K., and Warwick, J., 1999. Effects of the 1997 flood on the transport and storage of sediment and mercury within the Carson River valley, west-central Nevada: J. Geology, v. 107, p. 313-327.	Channel seds remained low after flood (1-5 ppm HgT)		Overbank seds increased in Hg conc (~20%) dnstrm from Brunswick Canyon. Hg conc greatest in B. Canyon. Hg conc high w/i 50 m of river & >~125 m of river, where coarsest (amalgam grains) & finest (silt-clay) sediments occur		Excellent study – relates flood effects to geomorphology & valley shape, channel width changes
Miller, J.R., Lechler, P.J., Rowland, J., Desilets, M., and Hsu, L.-C., 1996. Dispersal of mercury-contaminated sediments by geomorphic processes, Sixmile Canyon, Nevada, USA: Implications to site characterization and remediation of fluvial environments. Water, Air, and Soil Pollution, v. 86, pp. 373-388.	Hg-contam deposits cover only 21% of fan, & avg 103.7 ppm				
Miller, J.R., Lechler, P.J., Rowland, J., Desilets, M., and Hsu, L.-C., An Integrated Approach to the Determination of the quantity, Distribution, and Dispersal of Mercury in Lahontan Reservoir, Nevada, USA. J Geochem. Expl. Vol. 52, pp. 45-55.	Good correla of Hg w silt+clay, org C, & with+I16 earliest post-1915 deposits				
Rowe, T.G., Lico, M.S., Hallock, R.J., Maest, A.S., and Hoffman, R.J., 1991. Physical, chemical, and biological data for detailed study of irrigation drainage near Stillwater, Fernley, and Humboldt Wildlife Management Areas and Carson Lake, west-central Nevada, 1987-89. U.S. Geological Survey Open-File Report 91-185. Carson City, Nevada.	Mostly < 1 ppm Hg; only 3 of 31 samples are > 1 ppm Hg	Mostly < 0.1 ug/L, but ranges up to 2.6 ug/L		High in SWMA & Carson Lake (note values are dry wt.)	Very little text or interpretation in this report. Focus is on drainage water quality
Tidball, R.R., Briggs, P.H., Stewart, K.C., Vaughn, R.B., and Welsch, E.P., 1991. Analytical data for soil and well core samples from the Carson River basin, Lyon and Churchill counties, Nevada. U.S. Geological Survey Open-File Report 91-584A. 140 p.			Hg ranged in surface soils from <0.02-140 mg/kg; subsurface soils ranged from <0.02-20 mg/kg, but only 3 of the 91 samples exceeded 1 ppm		Used in HHRA
Tuttle, P.L., and Thodal, C.E., 1998. Field screening of water quality, bottom sediment, and biota associated with irrigation near the Indian Lakes area, Stiilwater Wildlife Management Area, Churchill County, west-central Nevada, 1995. USGS Water-Resources Investigations Report 97-4250	Hg ranges <0.02 to 0.19 ppm. Latter value exceeds concentration associated with toxicity to benthic freshwater organisms	Seepage ponds were ND for Hg at 0.1 ug/L; no subsequent analyses for Hg		Hg in eggs not of concern; Hg in 4 of 6 livers > 1.3 ppm (assoc w decreased production)	Not much avian use cf other wetlands in 1995

Table 1
Summary of Available Primary Data
Carson River Mercury Site, OU2

Reference	Year Published	Data Collected				Region	Data Quality
		Sediments	**Surface Water**	**Overbank/Floodplain/ Soil**	**Biota**		
Tuttle, P.L., Higgins, Damian K., and Quashnick, J., 2001. Mercury characterization in Lahontan Valley wetlands, Carson River mercury site, Lyon and Churchill counties, Nevada, 1999, US Fish and Wildlife Service, Div. of Environmental Contaminants, Reno, NV.	2001	25 samples for HgT & MeHg (0-3 cm)	21 samples for unfiltered MeHg & HgT, 11 samples for dissolved HgT & MeHg	–	68 aquatic invertebrates – corixids (water boatmen) for HgT & MeHg	39 wetlands in Lahontan Valley, including in Stillwater NWR **(2D)**	High
U.S. Geological Survey water-quality monitoring stations	1997 – present (ongoing)	HgT and MeHg often available for one or more locations	Unfiltered and filtered MeHg, HgT for each station; MeHg and HgT in suspended sediments often available	–	–	Collected at USGS gages at Carson City, Ft. Churchill, Below Lahontan Dam; need to check for others **(2A, 2C)**	High
Unpublished reports or data: Mercury in Fish Collected from the Indian Lakes System (Tuttle, US FWS); Indian Lakes Soil & Water Samples	1992, 1993	Some samples are actually in lakes and thus are sediment samples, but they all were classed as soil samples	7 water samples analyzed for metals, major cations and hardness	27 samples from 23 locations across Indian Lakes area; sampled at 0-6, 21-27 inches (only 4 deep spls)	Composite muscle samples of 5 carp, 4 white bass, 2 white crappie, 1 channel catfish	Indian lakes area of Stillwater WMA **(2D)**	High – though unpublished, data validation was done
Unpublished USBR Draft Worklpan (9/17/92) and Data Report for Carson Lake Pasture (2/20/93)	1992, 1993	133 samples: 90 from Carson Lake pasture & at 0-6, 21-27, & 57-63 inches. 33 samples from 25 locations along shore of Lahontan Reservoir, at 0-6 & 6-12 inches (only 8 samples from greater depth at Lahontan)		Some of the Carson Lk samples are now in pasture, though they were part of Carson Lake when it had water. Classifying all these samples as sediments.		Lahontan & Carson Lk pasture **(2B, 2C)**	High – though unpublished, data validation was done
Van Denburgh, A.S., 1973. Mercury in the Carson and Truckee river basins of Nevada: U.S. Geological Survey Open-File Report 73-352, 14 p.	1973	Sampled from Dayton to Lahontan Reservoir, analyzed for HgT	Unfiltered water sampled 1970-72 from Dayton and Lahontan Reservoir, analyzed for HgT			Dayton to Lahontan Res **(2A, 2B)**	
Wayne, D.M., Warwick, J.J., Lechler, P.J., Gill, G.A., and Lyons, W.B., 1996. Mercury contamination in the Carson River, Nevada: A preliminary study of the impact of mining wastes. Water, Air, and Soil Pollution vol. 92, p. 391-408.	1996	50 samples from channel analyzed fr HgT	11 samples (7 from Carson R., 4 from Lahontan Reservoir) for filtered & unfiltered HgT	38 bank & 7 tailings samples for HgT	–	Carson River upstream from reservoir; Lahontan Reservoir **(2A, 2B)**	High

Reference	Observations/Summary of Collected Data				Notes of interest
	Notes on Sediment Splg Results	**Notes on Water Splg Results**	**Note on Overbank/Floodplain/ Soil Sampling Results**	**Notes on Biota Splg Results**	
Tuttle, P.L., Higgins, Damian K., and Quashnick, J., 2001. Mercury characterization in Lahontan Valley wetlands, Carson River mercury site, Lyon and Churchill counties, Nevada, 1999, US Fish and Wildlife Service, Div. of Environmental Contaminants, Reno, NV.	HgT progressively declines in sequential wetlands in the flow-thru system; MeHg in sed correls w HgT in sed., also declining w dist dnstrm. No difference b/w sed MeHg in historic & constructed wetlands.	Most HgT and MeHg exists in particulate phase. No difference in water-column MeHg b/w historical and constructed wetlands.		Most Hg was MeHg. Statistically signif relationship b/w MeHg in corixids & sed --> sediment plays a key role in bioavailability. MeHg higher in constructed wetlands. Weak negative correlation of MeHg in corixids with pH.	BAFs (bioaccumulation factors) higher in constructed wetlands than historical wetlands
U.S. Geological Survey water-quality monitoring stations		MeHg below reservoir has been high (up to 35.2 ng/L) in high-flow water years (max reservoir level 4160.9 ft). Limnological profiling in 2006 showed pronounced reservoir stratification, & MeHg reached 40.2 ng/L near bottom, 6.5 near thermocline, and 0.6 in epilimnion.			Consistent with limnological data from Cooper et al., 1983
Unpublished reports or data: Mercury in Fish Collected from the Indian Lakes System (Tuttle, US FWS); Indian Lakes Soil & Water Samples		All Hg results ND at 0.2 µg/L	Hg only locally anomalous: only 2 samples > 1 ppm, both in 0-6" interval. Deeper samples even lower in concentration.	Bass had highest Hg (1-2.7 ppm ww), followed by crappie, carp & catfish (all spls of latter 2 below 1 ppm)	Primarily data tabulation & 1 map, but data validation was done
Unpublished USBR Draft Worklpan (9/17/92) and Data Report for Carson Lake Pasture (2/20/93)	Strong enrichment in Hg in shallow soils at Carson Lk pasture: 0-6" mean = 4.77 mg/kg, max = 12.9 mg/kg; 21-27" mean = 0.72 mg/kg, max = 3.5 mg/kg; 57-63" mean = 0.13 mg/kg, max = 0.34 mg/kg. At Lahontan shore, all results low (<0.1 to 0.3 mg/kg), & no depth pattern.				Primarily data tabulation & 1 map, but data validation was done
Van Denburgh, A.S., 1973. Mercury in the Carson and Truckee river basins of Nevada: U.S. Geological Survey Open-File Report 73-352, 14 p.	Hg ranged 0.31 to 11 mg/kg upper zone (Dayton to Ft Churchill), with background upstrm from mills <0.1 mg/kg; increases to 12 to 20 mg/kg in upper basin of Lahontan Res	Ranged from 500 to 6300 ng/L HgT			First Hg sampling study in area
Wayne, D.M., Warwick, J.J., Lechler, P.J., Gill, G.A., and Lyons, W.B., 1996. Mercury contamination in the Carson River, Nevada: A preliminary study of the impact of mining wastes. Water, Air, and Soil Pollution vol. 92, p. 391-408.	0.58 ppm above Dayton, 2.1 below	Both filt & unfilt HgT inc steadily to upper por of Lah. Res. (but a high-turbidity year)	Bank & tailings up to 250 & 881 ppm HgT, resp		

Table 2
Review of Available Data Against Potential Risk Factors
Carson River Mercury Site

Risk Factors		Available data	Possible Deficiencies
Human Health Risk			
1. Inhalation of impacted dust and/or vapor			
a.	Is Hg present in the surface materials available for windblown transport?	Risk was evaluated in HHRA using derived values based on Bureau of Recreation results for Lahontan beach areas.	No direct readings of windblown dust. No other areas evaluated beyond Lahontan beaches.
b.	Is Hg volatilizing from soils, sediment deposits, or impacted surface waters?	Indoor air samples collected from 15 homes in Dayton area for HHRA. Volatilization from surface water not evaluated (considered implausible) in HHRA. Surface emissions from lake at one location at Lahontan Reservoir over 24-hr period.	Air samples from areas with elevated MeHg such as terminal wetlands.
2. Ingestion of impacted water, food (e.g., fish) and crops irrigated with impacted surface water and/or groundwater			
a.	Are impacted fish or other impacted biota being used as recreational or subsistence food sources?	Significant volumes of available data from multiple sources for fish and waterfowl. Risk was evaluated for both recreational and subsistence fishing and waterfowl from throughout CRMS in HHRA.	
b.	Are crops irrigated with Carson River water impacted, and are they a food source for biota or humans?	Vegetables and fruits sampled from gardens in Dayton area for mercury uptake from soil for HHRA. Risk from tules in Fallon area qualitatively evaluated in HHRA.	No irrigated crops sampled.
c.	Is Hg present in surface water or groundwater at levels that may pose a risk if ingested?	Groundwater sampled from 32 homes in Dayton area for HHRA. Surface water was not evaluated in HHRA as Carson River not considered a source of drinking water.	Groundwater evaluation in HHRA limited to Dayton area only. No evaluation of surface water performed in HHRA.
3. Dermal exposure to impacted soil, sediment, surface water and/or groundwater			
a.	Is Hg present in surficial soils and sediments where humans may be exposed by direct contact?	Representative surface soil samples collected from mill sites, alluvial fan, floodplain above and below Lahontan Dam for HHRA, and beach deposits from Lahontan, Indian Lakes and Washoe Lake referenced.	Data collected for representative risk, with no effort towards defining “nature and extent” of mercury.
b.	Is Hg present in surface water at levels that may pose a risk to humans if exposed through wading or swimming?	Not considered a complete pathway in HHRA due to low concentrations in surface water.	

Table 2
Review of Available Data Against Potential Risk Factors
Carson River Mercury Site

Risk Factors		Available data	Possible Deficiencies
c.	Is Hg present in groundwater at levels that may pose a risk if used for washing or showering?	Not considered in HHRA due to poor absorption from dilute solutions.	
Ecological Risk			
1. Conversion of mercury into more readily bioavailable methylmercury			
a.	What are the cause(s) of the conversion of Hg to MeHg	Numerous studies discuss methylation by sulfate-reducing bacteria in low DO conditions.	Not clear on methylation in Carson River in Dayton area with high DO conditions.
b.	Where is the conversion occurring?	Methylation is occurring in sediments within the Carson River, Lahontan Reservoir, Carson Sink, agricultural drains, and terminal wetlands (USGS, 2001).	No clear cause on methylation in Dayton area. Previous studies indicate lowest methylation rates in upper Carson River area.
2. Entry of methylmercury into the food chain			
a.	Is MeHg entering the food chain at the lowest trophic levels (e.g., phytoplankton) and biomagnifying up the food chain?	Results from macroinvertebrates and insectivorous birds and fish show Hg impacts in multiple studies.	No data for Hg in algae/ phytoplankton identified.
3. Bioaccumulation and biomagnification of mercury in higher trophic levels			
a.	Is MeHg bioaccumulating in and biomagnifying up the food chain (e.g., phytoplankton to zooplankton [microinvertibrates] to insects [macroinvertebrates] to fish to piscivorous fish and birds?	Aquatic insectivorous birds show moderate Hg impact. Piscivorous fish and birds show highest impacts from Hg in multiple studies.	
4. Direct exposure of fish and birds to methylmercury in surface water			
a.	Does direct exposure to elevated Hg in surface waters have any effect on the higher trophic levels?	Unfiltered samples of Hg from Stillwater exceeded the Nevada chronic aquatic life standards, however, filtered samples were below the standards. Most Hg is in particulate phase within the wetlands (USFW, 2001).	